

CLAIMS

Therefore, having thus described the invention, the following is claimed:

1. A method of three dimensional lithography, comprising:
 - providing a substrate having at least one optical element, wherein the optical element is selected from a refractive element and a diffractive element;
 - disposing a polymer layer on the substrate and the at least one optical element, wherein the polymer layer includes a polymer material selected from a positive-tone polymer material and a negative-tone polymer material;
 - positioning a mask adjacent the polymer layer, wherein the mask does not cover at least one directly exposed portion of the polymer material directly overlaying the at least one element; and
 - exposing the at least one directly exposed portion of the polymer material to optical energy, wherein the optical energy passes through the at least one directly exposed portion of the polymer material and interacts with the element, and the element redirects the optical energy through the polymer material forming at least one area of indirectly exposed polymer material.
2. The method of claim 1, wherein the polymer material includes the positive-tone polymer material and further comprises:
 - removing the at least one area of indirectly exposed polymer material and the at least one directly exposed portion of the polymer material.

- 1 3. The method of claim 1, wherein the polymer material includes the positive-tone
2 polymer material and further comprises:
3 forming tunnels within the polymer material where the at least one area of
4 indirectly exposed polymer material is removed.
- 1 4. The method of claim 1, wherein the polymer material includes the positive-tone
2 polymer material and further comprises:
3 forming slanted polymer layer walls by removing the at least one area of
4 indirectly exposed polymer material.
- 1 5. The method of claim 1, wherein the polymer material includes the negative-tone
2 polymer material and further comprises:
3 removing the polymer material except for the at least one area of indirectly
4 exposed polymer material and the at least one directly exposed portion of the
5 polymer material.
- 1 6. The method of claim 1, wherein the polymer material includes the negative-tone
2 polymer material and further comprising:
3 forming a polymer structure having at least one slanted polymer wall by
4 removing the polymer material except for the at least one area of indirectly
5 exposed polymer material and the at least one directly exposed portion of the
6 polymer material.

- 1 7. The method of claim 6, wherein the polymer structure is selected from a “W”-
2 shaped polymer structure and an “L”-shaped polymer structure.

1 8. A method for nano-indentation, comprising:
2 providing a substrate having a polymer layer disposed on the substrate, the
3 polymer layer includes a polymer material that is in an uncured plastic state;
4 providing a stamp mask having a photomask and at least one nano-
5 indentation structure for forming a physical feature on the polymer layer, wherein
6 the photomask does not cover at least one area of the polymer material; and
7 stamping the polymer material with the stamp mask, wherein the polymer
8 material forms the physical feature caused by the at least one nano-indentation
9 structure.

1 9. The method of claim 8, further comprising:
2 exposing the at least one portion of the polymer material to an optical
3 energy to form at least one exposed area of polymer material.

1 10. The method of claim 9, further comprising:
2 curing the polymer material, wherein the at least one exposed portion of
3 polymer material is removed, wherein the polymer material not exposed to the
4 optical energy is cured.

- 1 11. The method of claim 8, further comprising:
2 curing the polymer material, wherein the at least one exposed portion of
3 polymer material is cured, wherein the polymer material not exposed to the
4 optical energy is removed.
- 1 12. The method of claim 8, further comprising:
2 forming a polymer structure having the physical feature.
- 1 13. The method of claim 8, wherein the physical feature is selected from a multi-tooth
2 physical feature, a “seat” shaped physical feature, a single point (triangle tip)
3 physical feature, a double point (inverted triangle tip) physical feature, a crescent
4 shaped physical feature, and a half-circle physical feature, and combinations
5 thereof.

- 1 14. A method of forming a structure, comprising:
- 2 providing a substrate having at least one element and a polymer layer, the
- 3 polymer layer is disposed on the substrate and the at least one element, wherein
- 4 the polymer layer includes a polymer material selected from a positive-tone
- 5 polymer material and a negative-tone polymer material, wherein the polymer
- 6 material is in an uncured plastic state, and wherein the element is selected from a
- 7 refractive element and a diffractive element;
- 8 providing a stamp mask having a photomask and at least one nano-
- 9 indentation structure for forming a physical feature on the polymer layer, wherein
- 10 the photomask does not cover at least one directly exposed portion of the polymer
- 11 material;
- 12 stamping the polymer material with the stamp mask, wherein the polymer
- 13 material forms the physical feature caused by the at least one nano-indentation
- 14 structure; and
- 15 exposing the at least one directly exposed portion of the polymer material
- 16 to optical energy, wherein the optical energy passes through the at least one
- 17 directly exposed portion of the polymer material and interacts with the element,
- 18 and the element redirects the optical energy through the polymer material forming
- 19 at least one area of indirectly exposed polymer material.

1 15. The method of claim 14, wherein the polymer material includes the positive-tone
2 polymer material and further comprising:

3 removing the at least one area of indirectly exposed polymer material and
4 the at least one directly exposed portion of the polymer material.

1 16. The method of claim 14, wherein the polymer material includes the positive-tone
2 polymer material and further comprising:

3 forming tunnels within the polymer material where the at least one area of
4 indirectly exposed polymer material is removed.

1 17. The method of claim 14, wherein the polymer material includes the positive-tone
2 polymer material and further comprising:

3 forming slanted polymer layer walls by removing the at least one area of
4 indirectly exposed polymer material.

1 18. The method of claim 14, wherein the polymer material includes the negative-tone
2 polymer material and further comprising:

3 removing the polymer material except for the at least one area of indirectly
4 exposed polymer material and the at least one directly exposed portion of the
5 polymer material.

1 19. The method of claim 14, wherein the polymer material includes the negative-tone
2 polymer material and further comprising:

3 forming a polymer structure having at least one slanted polymer wall by
4 removing the polymer material except for the at least one area of indirectly
5 exposed polymer material and the at least one directly exposed portion of the
6 polymer material, wherein the polymer structure has the physical feature.

1 20. The method of claim 14, wherein the structure includes a waveguide having
2 surface relief features.

1 21. The method of claim 14, wherein physical feature is selected from a multi-tooth
2 physical feature, a “seat” shaped physical feature, a single point (triangle tip)
3 physical feature, a double point (inverted triangle tip) physical feature, a crescent
4 shaped physical feature, and a half-circle physical feature, and combinations
5 thereof.